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## Blast injuries of large tyres: Case series

Ashraf F. Hefny<sup>a</sup>, Hani O. Eid<sup>b</sup>, Mohamed Al-Bashir<sup>c</sup>, Fikri M. Abu-Zidan<sup>d,\*</sup><sup>a</sup> Department of Surgery, Al-Ain Hospital, Al-Ain, United Arab Emirates<sup>b</sup> Emergency Department, Tawam Hospital, Al-Ain, United Arab Emirates<sup>c</sup> Department of Surgery, Tawam Hospital, Al-Ain, United Arab Emirates<sup>d</sup> Department of Surgery, Faculty of Medicine and Health Sciences, United Arab Emirates University, PO Box 17666, Al Ain, United Arab Emirates

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## ABSTRACT

**Background:** Severe blast injuries of large tyres are similar to those resulting from landmine explosions with neither thermal nor chemical effects. Little has been written about the destructive nature of these blasts.**Aims:** To evaluate our clinical management of patients involved in large tyre blasts.**Patients and methods:** All patients who had tyre blast injuries and were admitted to Al-Ain or Tawam Hospitals between March 2003 and September 2009 were retrospectively studied. Clinical presentation, mechanism of injury, management, and outcome were reviewed.**Results:** Seven male patients were studied. They had a median (range) age of 38 (20–53) years. Four patients (57%) were inflating the tyre when it suddenly exploded. On arrival to the hospital, two patients were unconscious with GCS of 3/15. Six patients (86%) had head/face trauma. Three patients had multiple injuries to different body parts (43%). The median (range) injury severity score was 14 (10–33). Four patients (57%) were operated on. Five patients were admitted to the ICU with a median (range) ICU stay of 2 (1–2) days. The median (range) total hospital stay was 3 (1–14) days. Two patients died (overall mortality 29%).**Conclusions:** The high energy produced by large tyre blasts may cause severe injuries leading to high morbidity and mortality. Preventive occupational methods should be adopted and implemented at the work place.

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## 1. Introduction

Blast injuries have become more common in the past few decades causing thousands of casualties. These include bomb explosions, terrorist blasts, and industrial and home-related explosions.<sup>1,2</sup> Blast injuries of large tyres are similar to those resulting from landmine explosions but without thermal or chemical effects.<sup>3</sup> During servicing, explosion of an inflated large tyre may result in high morbidity and mortality. Young mechanics are usually the victims.<sup>4,5</sup> Few studies have been published on this important area.<sup>6</sup> Herein, we present our recent experience in the management of this serious problem.

## 2. Patients and methods

Patients who had tyre blast injuries and were admitted to either Al-Ain or Tawam Hospitals between March 2003 and September

2009 were retrospectively studied. The clinical presentation, mechanism of injury, management, and outcome were analyzed.

The Local Ethics Committee of Al-Ain Health District Area has approved data collection for all trauma patients who were admitted to Al-Ain and Tawam Hospitals or who have died in the Emergency Department to be entered into a Trauma Registry.

## 3. Results

There were seven patients studied. They had a median (range) age of 38 (20–53) years. Four patients were inflating a tyre when it suddenly exploded. On arrival to the hospital, two patients were unconscious with GCS of 3/15. Four patients (57%) had isolated trauma to the head while the others sustained multiple injuries to different body regions. Six patients had head injury (Fig. 1). The median (range) injury severity score was 14 (10–33). Four patients were operated on and were admitted to the ICU. Three patients were not operated on; two had comminuted fractures of the frontal bone which was treated conservatively (Fig. 2), the other patient had severe brain oedema with multiple body injuries. Five patients

\* Corresponding author. Fax: +971 3 7672067.

E-mail address: [fabuzidan@uaeu.ac.ae](mailto:fabuzidan@uaeu.ac.ae) (F.M. Abu-Zidan).



**Fig. 1.** Right extradural haematoma of 14 mm wide having air inside it associated with mild midline shift caused by a large tyre explosion.

were admitted to the ICU with a median (range) stay of 2 (1–2) days. The median (range) total hospital stay was 3 (1–14) days. Two patients died after admission; one had bowel evisceration associated with injuries to the pancreas, duodenum, ascending and transverse colon, inferior vena cava (IVC), and the right kidney. Right nephrectomy, repair of the IVC, right hemicolectomy, duodenal repair, gastrojejunostomy, and suturing of pancreatic capsule were performed. This patient was admitted to the ICU where he died 7 h later. The other patient had severe brain oedema, subarachnoid haemorrhage, fracture frontal bone, bilateral lung contusion, bilateral rib fractures, and right sided haemothorax for which chest drain was inserted. This patient died one day after admission to the ICU (Table 1).

#### 4. Discussion

The high energy produced by large tyre blasts may cause severe injuries. This type of severe work-related injury is underreported.<sup>7,8</sup> Five of our patients were mechanics while the other two were drivers. Four (57%) were inflating a large vehicle tyre when it suddenly exploded. Most large tyre blasts occur during inflating the tyre.<sup>6,9</sup> None of our patients was using protective equipments (such as safety cages) during work.

Large tyre blasts cause primary, secondary, or tertiary injuries.<sup>6</sup> The primary injury is caused by the initial pressure wave (shock wave) which can produce severe barotrauma leading to eye injuries and damage to air containing organs such as the lung, ear drum, and nasal sinuses.<sup>9,10</sup> This was well-demonstrated in the first patient who had a lung contusion associated with pneumothorax and pneumomediastinum. The clinical picture of blast lung injuries may become obvious within 24 h of the explosion. Admission of injured patients with blasts for an observation period of 24 h is essential.<sup>11</sup>

Secondary injuries are caused by the flying objects from the exploded tyre hitting the victims at high speed and resulting in complex injuries. The locking ring of the tyre may turn into a dangerous object as it flies out from the explosion center.<sup>12,13</sup> This

effect was clearly demonstrated in patient No 4, where the ring caused evisceration of his bowel and amputation of his right arm.<sup>14</sup> Tertiary counter-coup injuries are produced as the patient is thrown away against surrounding walls, the ground, or other objects causing serious injuries.<sup>8,12,15</sup>

The initial evaluation and treatment of our patients followed the Advanced Trauma Life Support Program guidelines through establishing a patent air way with cervical spine protection, ventilation and oxygenation, haemorrhage control and circulation stabilization, and prevention of hypothermia. The patients were first assessed for life threatening injuries and managed accordingly. When the patient becomes stable, attention was then turned to injuries that may jeopardize the vital functions of the limbs, eyes and genitalia.<sup>16</sup>

Head and face are commonly injured.<sup>17,18</sup> This is because injured victims usually face the wheel. The head then becomes the target for the flying objects of the explosion. Six of our patients (86%) had head and face injury. Limb injuries are usually complex with significant soft tissue involvement. Three of our patients (43%) had limb injuries (Fig. 3). Patients may need multiple surgical procedures and long rehabilitation periods that end with a significant disability.<sup>7</sup> Four of our patients were operated on. The overall mortality rate of reported large tyre blast injuries is 19%.<sup>6</sup>

Two of our patients with the highest ISS (33, 27) died (a mortality rate of 29%). One of them was brought to the Emergency Department unconscious and hypotensive. He had a serious abdominal injury and died 7 h after laparotomy (patient No 4). Damage control surgery should have been adopted in this patient, although it may not have changed the outcome. The other patient had severe head injury with GCS of 3/15. He was admitted to the ICU where he died on the second day (patient No 2).

Prevention should be our ultimate goal because it is the most cost effective tool to reduce the impact of injury.<sup>19</sup> Complete tyre deflation and tyre servicing with adequate equipment are the most important preventive measures.<sup>20</sup> The United Arab Emirates (UAE) is a rapidly developing country having major construction projects and expanding supporting infrastructure. Employing large number of workers make it difficult for the local authority to control and prevent occupational injuries.<sup>21</sup> Hot weather in summer may be an



**Fig. 2.** Multiple fractures of the frontal bone caused by the rim of a large tyre.

**Table 1**

Demography, injuries, management and outcome of blast injured patients by large tyres in Al-Ain City 2003–2009 (n = 7).

Patients	Age (years)	Systolic BP (mmHg)	GCS	Pulse (bpm)	Most severe injuries	ISS	Management	ICU stay	Hospital stay	Outcome
1	25	120	15	75	Lacerated wound of the face. Lung contusion, Pneumothorax Pneumomediastinum Compound fracture of the left 3rd, 4th and 5th left proximal phalanges	11	Bronchoscopy K-wire fixation of the proximal phalanges	2	3	Survived
2	53	120	3	130	Facial laceration, Brain oedema, Subarachnoid haemorrhage, Multiple bilateral rib fractures, Lug contusion, Right haemothorax, Right forearm laceration	33	Chest tube insertion	1	1	Died
3	45	140	15	80	Lacerated wound of the scalp Fracture temporo-parietal bone Epidural haematoma Nasal bone fracture	21	Craniotomy	2	9	Survived
4	34	70	3	140	Abdomen evisceration Right arm amputation Left rib fractures	27	Laparotomy	1	1	Died
5	38	135	15	84	Lacerated wound of the scalp Comminuted fracture frontal bone	14	Conservative	0	5	Survived
6	46	130	11	75	Comminuted fracture of both maxilla Fracture zygomatic arch Fracture nasal bone and mandible	10	Open reduction and internal fixation of mandible, Orbital floor reconstruction	2	14	Survived
7	20	145	15	89	Compound comminuted fracture of right frontal bone	13	Conservative	0	2	Survived

added factor for tyre explosions by increasing the pressure inside the inflated tyre. The head was the most common injured region in the present study while it was the upper limb when all occupational injuries are considered.<sup>21</sup> Helmets and facial shields usage could have reduced the severity of head injury in our patients. Usage of safety cages can reduce the percentage of injuries occurring during inflation of tyres (in our series 57% of blasts occurred during tyre inflation). However, tyre blasts may occur during tyre repair. The workers can use safety cages only during tyre inflation but not during tyre repair, mounting or dismounting of a wheel, or rolling the tyre in the shop floor. Furthermore, barotrauma as a result of tyre blasts cannot be prevented by the safety cages. Increasing the public awareness, establishing standards for training in workplace and adequate equipment usage during servicing large vehicle tyres are essential.<sup>22</sup> These preventive measures should be promoted in our community where the level of work safety is low.<sup>23</sup>

In summary, the high energy produced by large tyre blasts may cause severe injuries leading to high morbidity and mortality. Increasing the awareness of this serious problem is essential. Preventive occupational methods should be implemented in work places, monitored, and enforced by the law.

#### Conflict of interest

None.

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#### Ethical approval

The Local Ethics Committee of Al-Ain Health District Area, Al-Ain, UAE (RECA/02/44).

#### References

- Hayda R, Harris RM, Bass CD. Blast injury research: modeling injury effects of landmines, bullets, and bombs. *Clin Orthop Relat Res* 2004;**422**:97–108.
- Pyper PC, Graham WJ. Analysis of terrorist injuries treated at Craigavon area hospital, Northern Ireland, 1972–1980. *Injury* 1983;**14**:332–8.
- Blechner MH, Seiler 3rd JG. Tire explosion injuries to the upper extremity. *J South Orthop Assoc* 1995;**4**:255–62.
- Bautista BN, Kernahan DA, Vistnes LM. Truck tire-rim injury – a new trauma entity. *Plast Reconstr Surg* 1971;**47**:117–21.
- Rautji R, Rudra A, Dogra TD. An unusual fatal injury due to tyre burst: a case report. *Forensic Sci Int* 2003;**138**:111–3.
- Hefny AF, Eid HO, Abu-Zidan FM. Severe tyre blast injuries during servicing. *Injury* 2009;**5**:484–7.
- Matloub HS, Prevel CD, Sanger JR, Yousif NJ, Devine CA, Romano J. Tire explosion injuries to the upper extremity. *Ann Plast Surg* 1992;**29**:559–63.
- Obafunwa JO, Busuttill A, Scott C. Fatal compressional injuries from a burst tyre: an industrial death. *J Clin Forensic Med* 1997;**4**:176–80.
- Li T, Mafee MF, Edward DP. Bilateral orbital emphysema from compressed air injury. *Am J Ophthalmol* 1999;**128**:103–4.
- Behbehani A, Abu-Zidan F, Hasaniya N, Merei J. War injuries during the Gulf War: experience of a teaching hospital in Kuwait. *Ann R Coll Surg Engl* 1994;**76**:407–11.
- Abu-Zidan FM, Aman S. Underwater explosion lung injury. *J Trauma* 2001;**50**:169.
- Murty OP. Tyre-blast injuries. *J Forensic Leg Med* 2009;**16**:224–7.



**Fig. 3.** Multiple fractures of bases of proximal phalanges caused by the sharp edge of the rim of the ruptured large tyre.

13. Eid HO, Abu-Zidan FM. Biomechanics of road traffic collision injuries: a clinician's perspective. *Singapore Med J* 2007;**48**:693–700.
14. Hefny AF, Eid HO, Salim K, Abu-Zidan FM. Medical image. Fatal tyre blast injuries including bowel evisceration and forearm amputation. *N Z Med J* 2008;**121**:72–3.
15. Irwin E, Lonnée H. Management of near fatal blunt laryngeal trauma. *Acta Anaesthesiol Scand* 2006;**50**:766–7.
16. American College of Surgeons. *Advanced trauma life support for doctors*. 7th ed. Chicago, IL: American College of Surgeons; 2004.
17. Lau G. An unusual case of pneumatically-induced facial and cervical injuries. *Forensic Sci Int* 1995;**73**:131–8.
18. Suruda A, Floccare D, Smith G. Injuries from tire and wheel explosions during servicing. *Ann Emerg Med* 1991;**20**:848–51.
19. Barss P, Smith GS, Baker SP, Mohan D. Occupational injuries. In: Barss P, Smith GS, Baker SP, Mohan D, editors. *Injury prevention: an international perspective*. New York: Oxford University Press; 1998. p. 219–32.
20. Sussman AM, Williams JS, Boyd CR, DeLoach ED. Multipiece tire rim injuries. *J Trauma* 1991;**31**:24–7.
21. Barss P, Addley K, Grivna M, Stanculescu C, Abu-Zidan F. Occupational injury in the United Arab Emirates: epidemiology and prevention. *Occup Med (Lond)* 2009;**59**:493–8.
22. U.S. Department of Labor. Occupational safety and Health Administration (OSHA). Servicing single-piece and multi-piece rim wheels. Available at: <http://www.osha.gov/Publications/osha3086.pdf>.
23. Tadros AM, Eid HO, Abu-Zidan FM. Epidemiology of foot injury in a high-income developing country. *Injury*; 2009 Jun29 [Epub ahead of print].